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AUTHOR Fields, Stephen C.
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ABSTRACT

Aptitude treatment interaction (ATI) for the two most widely used science teaching strategies (lecture method and lecture method augmented with classroom activities) was investigated. The aptitude variables examined were cognitive ability level expressed in Piagetian terms and cognitive learning style (field independence/dependence). A sample of 200 high school biology students (100 students for each treatment group) was utilized. Each treatment group was stratified for cognitive ability level. Achievement was measured in a criterion-referenced test to demonstrate mastery or non-mastery of eight biology concepts. Findings indicate that both aptitude variables interacted with achievement, and that the two treatments differed only marginally in the ATI. Of the two aptitudes analyzed, cognitive ability level had the greater interaction, namely, higher cognition favored mastery, while lower cognition did not. A strong correlation (zero-order gamma of .53 for each biology concept studied) was found between cognitive ability level and cognitive learning style. Being field independent and of a higher cognitive ability level was more indicative of achievement than being field dependent and of a higher cognitive ability level. Students of lower ability levels were more often field dependent and mastered the biology concepts infrequently. (Author/JN)

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Assessment of Aptitude Interactions for the Most Common Science Instructional Strategies

by

Stephen C. Fields

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Abstract

Many educational researchers neglect the aptitudes of the learners when they assess the relative effectiveness of instructional ploys. Critics of this approach question whether any strategy is best for learners of all aptitudes. The likely situation, as they see it, is that a successful strategy for learners possessing comparable characteristics may be inadequate for learners having differing aptitude traits. Research that probes the interaction of aptitudes with varying instructional strategies is termed A-T-I (Aptitude-Treatment-Interaction). It was the purpose of this study to examine A-T-I's for the two most widely used science teaching strategies (i.e., lecture and lecture augmented with classroom activities). Two aptitude variables were examined: cognitive ability level expressed in Piagetian terms and cognitive learning style (field dependence/independence). A sample of 200 high school biology students (100 for each treatment group) was utilized. Each treatment group was stratified for cognitive ability level. Achievement was measured in a criterion-referenced fashion (mastery vs. nonmastery of 8 biology concepts). The findings were that both aptitude variables interacted with achievement, and that the two treatments differed only marginally in the A-T-I. Of the two aptitudes analyzed, cognitive ability level had the greater interaction--i.e., higher cognition

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favored mastery, while lower cognition did not. A strong correlation (zero-order gamma of .53 for each biology concept studied) was found between cognitive ability level and cognitive learning style. Being field independent and of a higher cognitive ability level was more indicative of achievement than being field dependent and of a higher cognitive ability level. Students of lower ability levels were more often field dependent and mastered the biology concept infrequently.

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Assessment of Aptitude Interactions for the most Common Science Instructional Strategies

> The appropriate aim of applied research on instruction is to utilize knowledge about how instructional processes work to design "robust" instructional strategies, strategies which are so powerful that they are invulnerable to individual differences within normal ranges of aptitudes. (Gehlbach, 1979, p. 12)

As logical as this premise might seem, in practice many educational researchers neglect the aptitudes of the learners when they assess the relative effectiveness of instructional ploys. Critics of this approach question whether any strategy is best for learners of all aptitudes. The likely situation, as they see it, is that a successful strategy for learners possessing comparable characteristics may be inadequate for learners having differing aptitude traits.

With an increased awareness of individual differences among learners, a new paradigm of instructional theory has emerged. The basic premise of this paradigm is that <u>what is good for one student may not be appropriate for others</u>. Researchers of this paradigm use a methodology designed to account for individual differences of the learners. These differences are most frequently aptitude-based. For this research, the research design is termed A-T-I (Aptitude-Treatment-Interaction).

Early attempts to expose A-T-I's were primarily restricted by statistical designs insensitive to revealing inter-

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actions (Cronbach & Snow, 1977). Since the mid 1970's researchers have adopted methodologies that used regression analysis and the setting of confidence limits. These analyses, it was found, detect interactions with greater assurance.

As of late numerous relevant aptitudes have been identified (Snow, 1977; Cronbach & Snow, 1977). Two, in particular, are cognitive learning style (field dependence/independence) and cognitive ability level expressed in Piagetian terms (Holtan, 1982). Each of these aptitudes have been documented as predictors of academic achievement (Fields, Note 1; Fields, Note 2). Both have been implicated with A-T-I's as well (Snow, 1977; Cronbach & Snow, 1977; Gehlbach, 1979; Adams & McLeod, 1979; Holtan, 1982).

The predominant science classroom strategies are lecture and lecture augmented with classroom activities (Matthews, Schlitt, Mohamed, & Ray, Note 3). It was the purpose of this study to examine A-T-I's for these two strategies in high school biology classes. One analysis incorporated cognitive ability level as the aptitude variable, while another utilized cognitive learning style. Each analysis centered around criterion-referenced achievement of 8 biology concepts.

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Design and Methodology

Variables Studied

Dependent variables. Science achievement was assessed in terms of mastery or nonmastery of specific science concepts. The concepts utilized in the study were concepts typically incorporated into an introductory high school biology class. To determine the level of mastery for each of the concept tests, a KR-20 coefficient was computed after the tests were administered to the sample. This value was then used to compute mastery test coefficients (Livingston, 1972). This coefficient gives the reliability of a criterion-referenced test based upon the selected level of mastery. For each test, the pre-set level of mastery was that which provided a higher reliability than the KR-20 value and at the same time resulted in a minimum of 25% of the subjects (Ss) mastering the concept at that level. A lower level likely would have produced such low numbers that the analyses would have lost meaning and reliability for the hypotheses tested. Higher levels to be used as a cut-off might have produced, for some concepts, Ss who could have "mastered" the test with a low test score.

Each mastery test consisted of 12 multiple choice items assessing, in terms of Bloom's Taxonomy of educational objectives, comprehension, application, and analysis of each concept. These 12 items were selected from larger pools of

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items subjected to pilot testing with a sample possessing similar characteristics as this study's sample. The 12 items had item difficulty indexes of between 37.5 - 62.5% (percent of those getting the items correct).

Criterion-referenced (mastery) tests assessing concept comprehension should consist of a relatively small number of items. Otherwise, the test items, being somewhat repetitious of what is being asked, serve to teach some students the concept while they take the test (Stoker, Note 4). Since these tests must be concise, they do not lend themselves to traditional measures of internal consistency. Low reliability coefficients frequently occur, not because of weak internal consistency, but because traditional coefficients are biased toward tests of many items (Nunnally, 1978). For this reason, test-retest reliability coefficients were produced using a subsample of 45 Ss. Table A (refer to the Appendix) summarizes the KR-20, mastery test (mastery levels are in parentheses), and test-retest reliability coefficients for the 8 concepts analyzed.

A total of 12 concepts were studied. Two were used in pilot testing, and the remaining 10 were used in the study. Of the 10 concepts, 8 were randomly selected for formal analysis.

Independent variables. The two treatments served as independent variables. Both treatments employed the same

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verbal presentation of information, while one utilized prescribed small group or individual classroom activities in addition to the verbal instruction. Four teachers administered the treatments. Each of the teachers had at least one class of each treatment. To control consistency of presentation the teachers followed detailed instructional guides. Their classroom behaviors were monitored using the Science Curriculum Assessment System (Matthew, Phillips, & Good, 1977). Each treatment was a prescribed model in terms of the anticipated teacher behaviors. The monitoring of the teachers' behaviors during instructional sessions fostered conformity and consistency of instruction.

Control variables. Cognitive ability level and cognitive learning style served as control variables. Three levels of cognitive functioning were identified using a test of formal reasoning modelled after a test developed by Lawson (1978). This study viewed a concrete-operational (C-O) subject as having reasoning capabilities that were dependent upon concrete objects. A formal-operational (F-O) subject could consider all of the possible factors relevant to the solution of a problem and control for these while using deductive logic to solve the problem. The F-O subject was not bound to concrete objects. A transitionally-formal (T-F) subject displayed some characteristics of preformal thought. Since the S was viewed as being in an intermediate

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stage, the term "transitional" was used to convey this stage.

The instrument used to assess cognitive ability level was developed and validated in a previous study by this researcher. Most of the items utilized were found on a test developed by Lawson (1978). The remainder were items used on other tests ofcognitive ability. These items were of a spatial orientation (e.g., conservation of horizontality using a tilted test tube partially filled with water) since a variable in that study was the ability to perceive spatially.

The instrument was a written test using items validated on previous clinical and written tests of cognitive ability. With face validity provided in this manner, further validity was provided by having 3 other cognitive researchers familiar with the items review the test. The resulting test was reduced from 20 items to fifteen as a result of the critiquing by the independent examiners.

Reliability of the test was met in two ways. First, 75 Ss from the sample were given a clinical test using comparable items with standard protocols and apparatus. Assignment to the same cognitive ability levels using both the written and clinical tests was assessed. Both tests assigned Ss to the same cognitive ability level 84% of the time. Those not being assigned to the same ability level were on the borderline, in terms of their scores, between one cognitive ability level and another. This was not surprising, but did lower

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the reliability of the instrument.

A second measure of reliability was a test-retest reliability coefficient. A subsample of 100 Ss was used. The value was r_{12}=.89.

Cognitive learning style was measured using the Group Embedded Figures Test (Oltman, Raskin, & Witkin, 1971). The score on this test dichotomized Ss as either field dependent (FD) or field independent (FI). Pilot testing established a score ranging from 0-10 as identifying a FD S, while a score between 11-18 identified a S as being FI. For this study Douglass and Kahle (1978) provided the description of FD and FI:

> Field dependence/independence describes a generalized approach to one's interaction with the environment, including the analysis to problem solving tasks. An FI, or analytic, person is able to analyze a stimulus distinguishing, retaining, and coordinating relevant items extracted from a distracting background . . . . The FD person is unable to structure a stimulus and to perceive its parts as discrete from the overall field of reference. (p. 407)

Validity and reliability for the GEFT are provided in the test manual (Oltman, Raskin, & Witkin, 1971). Ehrlichman (1977) and Douglass and Kahle (1978) reported that the GEFT correlates well with other tests measuring the same construct. Researchers reporting reliabilities were Douglass and Kahle (1978) and Lawson (1983). Both reported a split-half reliability of .88. For this study, a test-retest reliability of .87 was found for a sample of 117.

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Questions and Hypotheses

Questions. Do A-T-I's exist in the two most frequently used science instructional strategies when cognitive ability level and cognitive learning style are examined? If so, do the interactions differ from one treatment to the other?

Hypotheses. The variables were of nominal scale strength. Using the typical nonparametric format to detect frequencies, the variables were tested for partial independence (i.e., assessing independence among achievement and the aptitude variable, while controlling for the treatments). For this type of analysis Everitt (1977) recommended this model:

$$H_0 = p_{ijk} = p_{..k}p_{ij.}$$

where p_{ijk} represented the probability of an observation occurring in the ijkth cell, and $p_{i..}$, $p_{.j.}$, and $p_{..k}$ were the marginal probabilities of the row, column, and layer variables respectively. The marginal probabilities were the following: rows (achievement), columns (aptitude variables), and layers (treatments). Three-dimensional contingency tables (2x3x2) were produced for each hypothesis.

The Sample

The written cognitive diagnostic instrument was administered to all students enrolled in average or advanced general biology at Heritage High School, Conyers, Georgia. Conyers is a suburb 20 miles east of Atlanta, Georgia.

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Whether a student took average or advanced biology was primarily based upon a teacher recommendation. There were a total of 4 advanced classes and 7 average classes. From a potential sample of 287 Ss, 236 completed all 10 concept units. To stratify the final sample for cognitive ability level, each treatment group consisted of 100 Ss.

The vast majority of the students were high school sophomores, and a few were juniors and seniors. The ages of the students ranged from 14-17 years of age with the mean age being 15 years and 7 months. The student population of Heritage High School was approximately 1600 at the time of the study. Most of the students came from middle to upper-middle income homes. The students were predominantly Caucasian (90%). The school was a comprehensive high school--academics and vocational training. Two-thirds of the senior class generally takes the SAT. Heritage ranks above the national average on both the verbal and mathematics components of the SAT.

Representativeness of the sample. The range of cognitive ability levels within the sample was comparable to those demonstrated in previous studies of high school biology students by Lawson and Renner (1975) and Lawson, Blake, and Nordland (1975). In terms of gender, the potential sample was approximately equal; there were slightly more females than males (150 females and 137 males). The final sample of 200 con-

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sisted of 104 females and 96 males.

Selecting the final sample. The cognitive ability test diagnosed 54% of the potential Ss as being C-O, 35% as being T-F, and 11% as being F-O. These same proportions were maintained in the analysis of the two treatments--i.e., each treatment group contained 54 C-O's, 35 T-F's, and 11 F-O's. From a pool of each ability level within each treatment, Ss were randomly selected at the conclusion of the study.

Statistics Applied to the Data

Contingency tables were constructed for each hypothesis of partial independence. The tables were 2x3x2. From these tables Chi-square (X^2) values were computed to test the null hypotheses of partial independence. To reduce the likelihood of falsely rejecting a null hypothesis when in fact it is true (see Good, 1984), alpha for this study was set at the .01 level.

Results

A-T-I for Cognitive Ability

Table 1 summarizes the findings for the interactions between achievement and cognitive ability for each of the treatments.

Insert Table 1 about here

The findings were significant ($p < .01$) for each of the 8

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concepts when the verbal approach was examined. The same was true for 6 of the concepts where the treatment was verbal, but augmented with individual or small group classroom activities.

With the indication that a similar interaction occurred for both treatments, hypotheses of partial independence (controlling for the cognitive ability levels of the Ss) were tested. Table 2 reveals that the treatments were essentially equivalent. Consequently, regardless of the treatment, cognitive ability did interact with achievement. In essence, higher cognitive ability levels favored achievement, while the converse was true for the lowest ability level. Table 3 depicts the percentages of all Ss mastering each concept by cognitive ability level.

Insert Tables 2 & 3 about here

A-T-I for Cognitive Learning Style

Achievement and cognitive learning style were examined while controlling for the two treatments. With a pre-set alpha of .01 there was an interaction in the verbal treatment for only 3 of the concepts and for only one concept in the verbal/activity treatment group--see Table 4.

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Insert Table 4 about here

With the findings showing a relatively weak interaction between achievement and learning style for both treatments, further tests examining treatment interactions seemed unimportant. Instead, it appeared more relevant to assess the interaction of both aptitude variables while controlling for achievement. Table 5 summarizes the findings for each concept. Table 5 also shows the results of the interactions for mastering and not mastering the concepts.

Insert Table 5 about here

The relationship implied by these findings was that individuals who were FI and of a higher cognitive ability level (T-F or F-O) tended to master the concepts, while C-O Ss who were FD did not. The implication here was that FI favored higher cognitive ability levels, while FD favored lower cognitive ability. The results parallel those of Douglass and Kahle (1978) and Shymansky and Yore(1980).

Conclusions and Discussion

This study suggests that neither treatment was superior in fostering achievement of the biology concepts studies. Variations in these methods or different emphases would like-

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ly lead to different findings. Still, as science educators, it is difficult to accept that a strictly verbal approach was as effective as a verbal strategy augmented with traditional biology activities.

In terms of A-T-I, both treatments revealed interactions between achievement and the two aptitude variables. The strongest aptitude variable was the cognitive ability level of the Ss. Though marginally important as an interacting variable alone, cognitive learning style correlated well (a zero-order gamma of .53 for each of the concepts) with cognitive ability level while controlling for achievement.

For practicing teachers these findings suggest that students who are of higher cognitive ability levels will achieve more often than those students of lower cognitive ability levels. Though developmental psychologists have been implying this for years, this study suggests that other aptitudes might enhance this consequence. For this study, being FI and of a higher cognitive ability level was a more significant indicator of achievement than merely being of a higher cognitive ability level. In a discordant fashion, being C-O and FD favored nonachievement. For C-O Ss who were FI achievement varied.

These findings, along with others, suggest that there are many potential interceding variables that affect achievement. Where exposing these is important, it is more important

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for educators to come to the realization that students differ in their characteristics and how they learn. Reliance upon one or very few instructional strategies will often be unproductive, if not irresponsible.

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Table A

Reliability Coefficients for the Concepts Analyzed

Concepts	KR-20	r_{CR} (mastery level)	r_{12}
Energy relationships	.58	.70 (9)	.86
Population density	.35	.71 (9)	.55
Growth rate	.68	.76 (8)	.88
Osmosis	.36	.61 (7)	.72
Photosynthesis	.52	.66 (7)	.82
DNA	.80	.84 (10)	.80
Enzymes	.62	.65 (7)	.79
Probability	.77	.80 (10)	.85

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Table 1

Cognitive Ability Level and Achievement While Controlling for the Treatments

Concepts	Verbal X^2	Verbal/Activity X^2
Energy relationships	24.42*	17.58*
Population density	20.13*	2.98
Growth rate	20.10*	24.29*
Osmosis	9.88*	2.18
Photosynthesis	13.51*	22.49*
DNA	10.58*	13.56*
Enzymes	16.42*	16.79*
Probability	18.40*	16.79*

df = 2 for each hypothesis

*p < .01

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Table 2

Treatments and Achievement While
Controlling for Cognitive Ability Level

Concepts	X^2	$p <$
Energy relationships	1.70	.90
Population density	6.54	.30
Growth rate	5.37	.50
Osmosis	1.94	.90
Photosynthesis	1.82	.90
DNA	3.36	.70
Enzymes	3.38	.70
Probability	.80	.98

df = 5 for each hypothesis

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Table 3

Percentage of Subjects Mastering Concepts

by Cognitive Ability Level

Concepts	% C-O	% T-F	% F-O
Energy relationships	19%	54%	82%
Population density	23%	50%	59%
Growth rate	23%	42%	96%
Osmosis	24%	35%	59%
Photosynthesis	19%	42%	82%
DNA	35%	70%	64%
Enzymes	33%	56%	96%
Probability	33%	63%	96%

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Table 4

Achievement and Learning Style While Controlling for the Treatments

Concepts	Verbal X^2	Verbal/Activity X^2
Energy relationships	.60	1.75
Population density	.99	1.24
Growth rate	5.21	3.76
Osmosis	9.61*	1.10
Photosynthesis	2.61	5.47
DNA	5.73	9.38*
Enzymes	7.81*	1.48
Probability	25.01*	.17

df = 1 for each hypothesis

*p < .01

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Table 5

Learning Style and Cognitive Ability Level While Controlling for Achievement

Concepts	Achievement X^2	Mastered X^2	Not Mastered X^2
Energy relationships	41.54*	9.81*	8.48*
Population density	23.29*	1.56	20.54*
Growth rate	39.53*	5.34	8.53*
Osmosis	41.15*	8.91*	7.76*
Photosynthesis	35.88*	3.74	10.70*
DNA	31.96*	4.14	9.82*
Enzymes	30.32*	5.78	9.26*
Probability	36.54*	4.01	8.32*

df = 5 for hypotheses of achievement

df = 2 for hypotheses of mastered and not mastered

*p < .01

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